DEVELOPMENT OF PHOTOVOLTAIC (PV) BASED ELECTRICAL POWER GENERATION

MUHAMMAD HAFIZUDDIN HANIM BIN ABDUL HAMID

ELECTRICAL & ELECTRONICS ENGINEERING
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by

Muhammad Hafizuddin Hakim Bin Abdul Hamid

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the requirements for the
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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

____
(Assoc. Prof. Dr. Balbir Singh Mahinder Singh)

ASSOC. PROF. DR. BALBIR SINGH
Senior Manager
Academic Central Services

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMMAD HAFIZUDDIN HAKIM BIN ABDUL HAMID

ABSTRACT

The demand of electricity becomes higher every year and the Ninth Malaysian Plan, it is projected that the need for electricity will increase by 20% in the year 2010. Power generation system in Malaysia is centralized and is based on non-renewable fuels such as coal, diesel, oil and natural gas. The price of natural gas is currently highly volatile and faces the possibility of depletion sooner than projected. In this project, a study is carried out to determine the effectiveness of the current electricity generation, transmission and distribution system. Long distance transmission by centralized power generation system involves energy loss. An alternative for the current system is decentralized power generation and which a power generator is built near to the load. Through this project, it is found that one of the advantages associated with distributed power generation is the opportunity for solar electricity generating system (SEGS) to be integrated to increase the efficiency of electrical distribution and to reduce power loss during transmission. The result obtained from this study includes potential of renewable energy to be implemented in power generation, possibilities of integrating PV based electricity generating system with distributed generating system and comprehensive sizing data for the implementation.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia's total available generating capacity in Peninsular Malaysia in 2008 was at 19,723MW. The generated electricity from 15 IPP's was 67.8% or 13,377MW of the total capacity and 32.2% or 6346MW was provided by TNB [1]. The demand of electricity will keep on increasing yearly and the Malaysia government planned to build more power plants progressively. One of the power plants that was completed by the end of year 2009 is 1400MW coal–fired power plant at Mukim Jimah, Port Dickson, Negeri Sembilan. By the end of 2010, the accumulated installed capacity is expected to increase to 25,258MW [2].

Table 1: Installed electricity generating capacity [3].

Generator	Generating Capacity	Percentage
Mini Hydro	43 MW	0.2%
Hydro	2072 MW	10.3%
Conventional Thermal (oil/gas)	1560 MW	7.8%
Conventional Thermal (coal)	3800 MW	18.9%
Gas Turbine	4521 MW	22.5%
Combined Cycle	7631 MW	37.9%
Diesel	492 MW	2.5%

According to the Ministry of Energy, Green Technology and Water, natural gas is still a major primary energy input for electricity generating sector constituting 68%, where 63.8% of installed electricity generating plants are based on natural gas. The average demand for natural gas in Peninsular Malaysia increased from 1,643 mmscfd in 2000 to 2,141 mmscfd in 2005. The power sector continued to be the major consumer of natural gas accounting for 66%, followed by the non–power sector at 28% and the remaining 6.0% was reserved for export market. To meet the increasing demand from the non-power sector, the Natural Gas Distribution System (NGDS) was expanded from 455 kilometers to 1,365 kilometers [3].

The natural gas reserves in Malaysia which are found on the offshores of East Coast of Peninsular Malaysia, Sarawak and Sabah, stood at 88.0 trillion standard cubic feet (tscf) or 14.67 billion barrels of oil equivalent as at 1st January 2008. The natural gas is expected to last for another 36 years and finding alternatives to the power plants which consume large amount of natural gas is needed [2]. Renewable energy such as solar, wind, biomass, tidal and geothermal energy utilizes all the natural available resources that are endless.

The Ninth Malaysian Plan effective from 2006 to 2010 targets 350 MW of grid-connected renewable electricity by 2010 [4]. Electricity generation from renewable resources has the potential to bridge the gap between demand and supply of power. Solar has good potential and the direct conversion technology based on PV has several positive attributes such as there will be no mechanical moving part, no high temperature, no noise and no pollution. Besides that, PV module has a very long life time and the energy source is free and available every day [5].

PV-based electrical power generation is developing and helping to reduce the dependence and consumption of fossil fuel for power generation. PV-based power generation has high potential to be utilized in Malaysia because the location of this country which is near to the equator and exposed to sunshine for almost 10 hours daily.

This project is about the study of the potential of implementing PV based electrical power generation system and to look into the transmission and distribution system. There are two types of electricity generation system which are centralized power generation and distributed power generation. Current generation system applied in Malaysia is centralized power generation system. The electricity generated in a large scale using fossil fuel and being transmitted over a long transmission line from the power plant to the consumer. The other generation system is distributed power generation system which is built near to the consumer. Distributed power generation system is an alternative to large scale source energy which could reduce the consumption of fossil fuels [6].The amount of losses along the transmission line could be reduced by implementing this approach. This study looks into the suitable power generation system concept to be implemented in PV based electrical power generation system.

1.2 Problem Statement

In the 9th Malaysian Plan, it is projected that the need for electricity will increase by 20% in the year 2010. The projection is important; as more power plants will be required, and the generation and distribution of electricity must be carefully planned, as the prices of fossil-fuels are highly volatile. Besides that, fossil fuels based electrical power generating system has the potential of influencing the climate and cause environmental pollution. The transmission of electricity over long distances by the centralized power generation further cause more losses. The current generation and distribution of electricity results in high losses and in order to compensate for the losses, there is a need to enhance the energy efficiency.

The development of PV-based electrical power generation system should be considered to reduce the dependency on fossil fuel gradually for power generation and increase the efficiency of electrical distribution system.

1.3 Project Objectives

The objectives of this project are:

- To carry out feasibility study on the implementation of distributed power generation.
- To look into the possibilities of integrating PV based electricity generating system with distributed generating system.
- To develop software for the implementation of PV based electrical power generation system.

CHAPTER 2
LITERATURE REVIEW

2.1 Current Electricity Generating Scheme

A centralized power generation is a power plant that uses fossil fuels such as natural gas, coal, diesel and oil to generate electricity. It is designed in large scale for continuous operation. This power plant needs mechanical moving parts such as compressor, turbines and generator in order to convert the heat from the combustion of fuel into mechanical energy which will then be converted into electrical energy.

The electricity generation stations owned by TNB or Independent Power Producer (IPP) are connected to the National Grid. National Grid is the transmission network which carried high voltage electricity. The voltage from National Grid will be step down by transformer at the transmission substation before it is distributed to the consumer via distribution network. The voltage produced at the generating station ranges from 11 to 20kV before it transformed to higher voltages of 500kV, 275kV, 132kV which are used for transmitting electricity over the grid system. The transformer at the substation reduces the voltage to 33kV, 22kV, 11kV, 6.6kV, 415V and 240V depending on the load. Figure 1 and Figure 2 shows the power station owned by TNB and National Grid distribution network.

Figure 1: TNB Power Stations.

Figure 2: National Grid distribution network.

Basically, the centralized power generation systems consist of three stages which are generation, transmission and distribution. This power generation system needs a long route before the electricity is supplied to the user. Figure 3 below shows the stages of generation, transmission and distribution in the centralized power generation system.

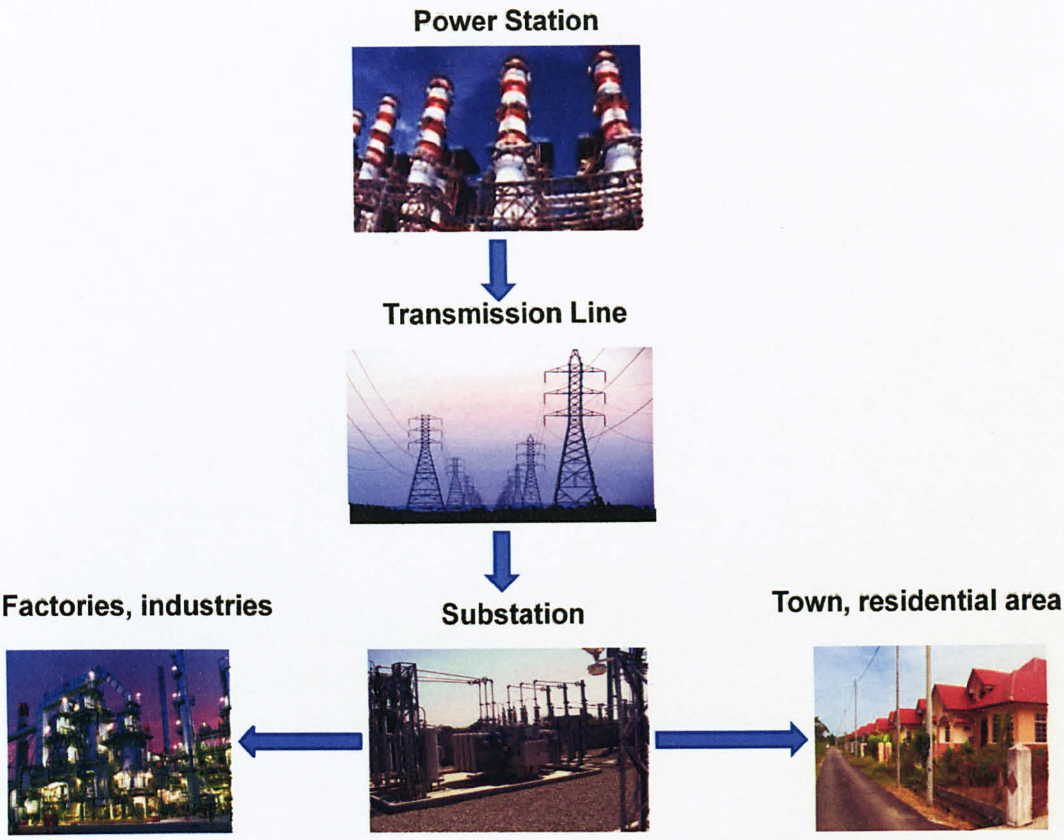

Figure 3: Stage of electricity transmission operated by the centralized power generation.

There is power loss in the process of generation and distribution of electricity. At the power plant, most of the power loss occurs at turbine and generator. Turbine and generator are involves in converting mechanical energy into electrical energy. Then, during the electricity distribution across the long overhead transmission line, the power loss will occur along the line. At the final stage, during the step down of the voltage, more losses occur.

2.2 World Scenario of Distributed Power Generation

The Distributed power generation scheme involves a small scale power generation system which is located near to the customer and the electric power source connected directly to the distribution network [7]. One of the advantages that cannot be provided by the large scale centralized power generation system is that the location is near to the customer; therefore the distributed power generation system can minimize the transmission and distribution losses. It also improves the supply reliability and power quality and the disruption of grid power failure can be prevented [8].

Distributed generation includes biomass based generators, combustion turbines, concentrating solar power and PV systems, fuel cells, wind turbines, micro-turbines, generator sets, small hydro plants, and storage technologies [9]. By locating power generation closer to the load, it might be able to solve several problems that occur in the centralized power generation which are reducing the dependency on fossil fuels and transmission and distribution losses [10]. It also could improve the quality of power and electrifying the rural villages. The distributed power generation can be categorized as in Table 2.

Table 2: Categories of Distributed Power Generation [6, 7]

Category	Distributed Generation Capacity
Micro	1W < 5kW
Small	5kW < 5MW
Medium	5MW < 50MW
Large	50MW < 300MW

Presently, there is a world-wide move toward using the distributed power generation system and other energy initiatives. The concern is about the environment and the opportunity for the development of renewable energy. High efficiency and cost effective of distributed power generation system has motivated the countries to implement this approach. Table 3 shows the capacity of distributed generation installed worldwide.

Table 3: Capacity of distributed generation installations in a sample of European countries [9]

Installed Distribution Generation (MW)								
	Diesel	**Cogen**	**Wind**	**Steam**	**Hydro**	**PV**	**Other**	**Total**
Austria		70	13.3		616	0.7		700
Belgium		1436	9.4		98		311	1843
Denmark	36	1811	2411	50	10	0.2	222	4540
Germany		2800	1545		3333	17	904	8599
France	610	435	8		450		250	1753
UK		4239	409		1475	1.2	643	6767
Italy	492	766	34		2159	5	252	3708
Spain		4522	1890		1362	1.26	426	8201
Switzerland		408	3			11	363	785
Norway		228	13		909			1150

2.3 PV Based Electrical Power Generation

There are three types of PV system which are stand–alone system, grid connected system and PV hybrid system. The design of the system is based on functionality, requirements, configuration and electrical loads [11]. PV system can be designed to provide DC or AC power.

2.3.1 Stand – alone System

The stand alone PV system is applied in isolated area where it is not possible to connect to the electricity network. Charge controller, batteries and inverter are needed for a stand–alone system. The function of charge controller is to maintain batteries at highest level of charge while protecting against overcharging by the PV array and from over discharge by the load. It also provides load control. Energy storage is supported by batteries and the inverter is needed to convert DC electricity to AC electricity.

However, the stand alone system is not sustainable because it is dependent on the weather. On a sunny day the system will produce much power and store it in the battery. During a cloudy day, it is less effective because the solar radiation of sunlight decreased. This stand alone system is not reliable because it depends on the availability of sunlight [12].

2.3.2 Grid Connected System

Grid-connected PV systems are designed to operate in parallel with the electric utility grid. The primary component in grid-connected PV systems is the inverter, or power conditioning unit (PCU). The PCU converts the DC power produced by the PV array into AC power consistent with the voltage and power quality requirements of the utility grid. A bi-directional interface is made between the PV system AC output circuits and the electric utility network which located at an on-site distribution panel or service entrance. This allows the AC power produced by the PV system to either supply on-site electrical loads or to back-feed the grid when the PV system output is greater than the on-site load demand.

2.3.3 PV Hybrid System

The hybrid power generation system is a combination of multiple sources to produce electricity. The auxiliary fuels for this system can be engine generator, wind generator, small hydro plant or other sources of electrical energy. On a sunny day, the PV will supply power to the battery storage and the wind generator will produce electricity during windy time. The wind generator could be more productive during monsoon season. The engine generator will supply electricity if the battery storage is empty or to meet the energy demand by the loads.

2.3.4 Key Components of PV based Electrical Power Generation

a) PV modules

PV modules will convert the exposed sunlight into electricity by the energy conversion process concept. The energized electrons result in the generation of electrical voltage. In other words, the energized electron flow is the DC current electricity. Several types of PV cells are monocrystalline, polycrystalline, amorphous silicon and thin films. Every type of PV cells is different in percentage of efficiency.

PV cells are connected electrically in series or parallel circuits to generate higher voltages, currents and power levels. PV modules made up of PV cell circuits sealed in the protective laminate and the fundamental building blocks of PV systems. PV panels include one or more PV modules assembled as a pre-wired and field-installable unit. A PV array is the complete power-generating unit, consisting of any number of PV modules and panels [13]. There are several types of PV modules available in markets which are monocrystalline, polycrystalline and amorphous silicon, also known as thin films.

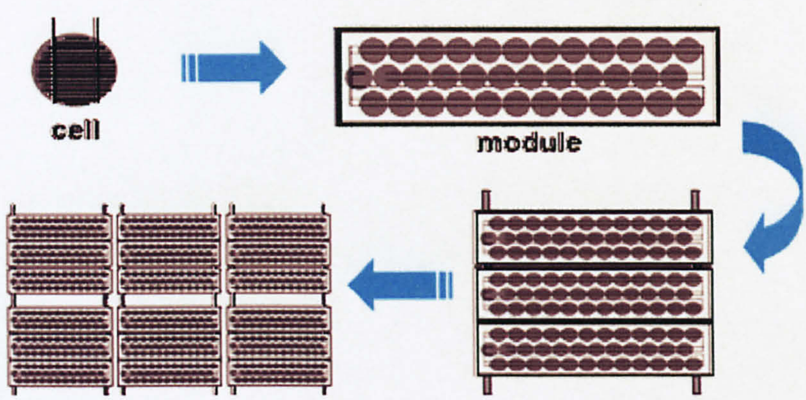

Figure 4: Photovoltaic cells, modules, panels and arrays [14].

b) <u>Battery Storage</u>

A battery is an electrochemical cell that can be charged electrically to provide a static potential for power or released electrical charge when needed. The main function of a battery is to store DC electricity from the PV generator for later use. The larger the capacity, the more energy can be stored. The batteries are able to supply power to loads at stable voltages.

c) <u>Controller</u>

The function of a controller is to maintain batteries at highest level of charge while protecting against overcharging by the PV array and from over discharge by the load. It also provides load control [15].

d) <u>Inverter</u>

An inverter is a device that converts DC power to AC power. The output of the charge controller is DC. Conversion to alternating current (AC) is required to supply the power for household.

e) <u>Auxiliary Generator</u>

The auxiliary generator is used as back up for stand - alone system and when there are failure in grid system. The common engine generator is fueled with diesel and it will produce AC electricity.

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

In this chapter, the methodology of the project that had been carried out through the project completion is described. Figure 6 shows the summarization of the project procedures. A Gantt chart requires the schedule and milestones for the project is attached in Appendix I.

In the early stage, the project involved the literature research on the power generation system which involves centralized power generation, distributed power generation and solar energy generating system. Knowledge on solar geometry, types of PV and its efficiency has been developed in this stage. The purpose of solar geometry research is to understand the behavior of solar radiation. Various sources of information such as journals, books and magazines were used during the research. A good understanding regarding the topic is really important to make sure the project will run smoothly. After understanding all the theory, the project was continued with data collection. Data collection was conducted in Putrajaya. It is the Malaysia government initiatives to develop Putrajaya as the green energy hub. Solar insolation was measured using the pyranometer. The measurement of solar insolation is the vital step in developing PV based electrical power generation system because the PV array sizing that will determine the output of the system is based on the solar insolation. The analysis of data collected is done to get the average solar insolation, availability of sunlight and reliability of the system.

The project is then continued by proposing the suitable method of power generation and distribution system. Distributed power generation is the electricity generation method chosen to integrate with PV based electrical power generation. The integrated system consists of PV power plant, auxiliary generator, battery bank, controller unit and load. Electricity is generated by PV power plant and generator as the auxiliary in case of low solar insolation during the rainy and cloudy days. Battery bank is used to store electricity generated by PV power plant for the consumption of electricity during night time. The controller unit consists of power controller, charge controller and inverter. The inverter is used to convert the electricity in PV based electrical power generation system from DC into AC power. A residential area with 20 houses is considered as the consumer of PV based electrical power generation system.

Next, the value of electrical load to be used for the system is to be estimated. The approach for load estimation is by collecting the Tenaga Nasional Berhad (TNB) electricity bills of various types of houses in Malaysia. The load average value obtained is to be used as reference value of load for the sizing calculation and simulation studies of PV based electrical power generation system. Simulation studies are carried out based on the conceptual and technical design and engineering calculation.

The final stage of this project is to develop software for the sizing purpose of the system. It is developed using Microsoft Visual Basic 2008. The software consists of load estimation, efficiency estimation, battery bank sizing and PV array sizing. The software will provide the most feasible outcome that can be used for the PV based electrical power generation implementation. The coding for the software using Microsoft Visual Basic 2008 is attached in Appendix VII. Figure 5 shows the structure of software developed.

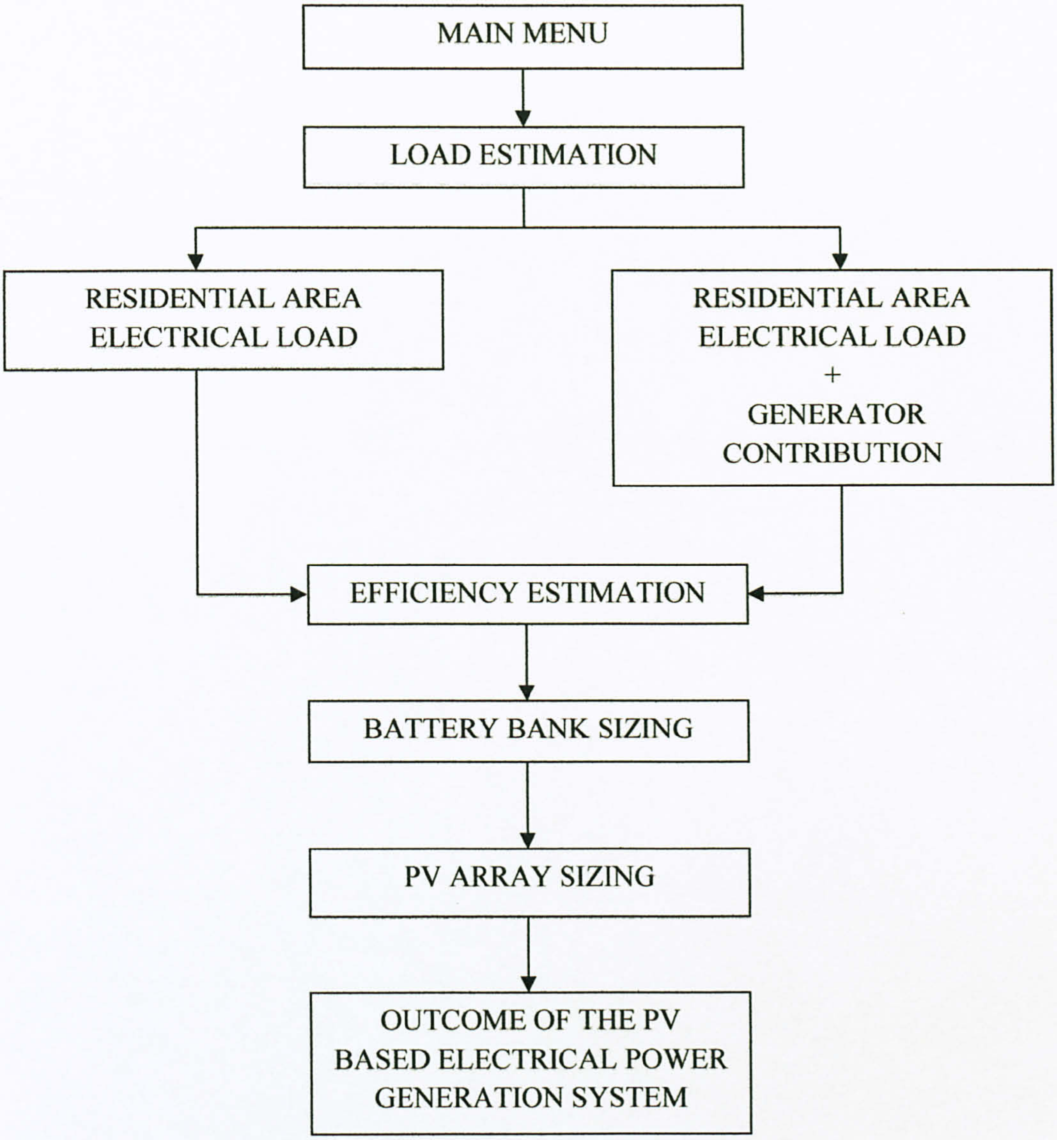

Figure 5: Structure of the software.

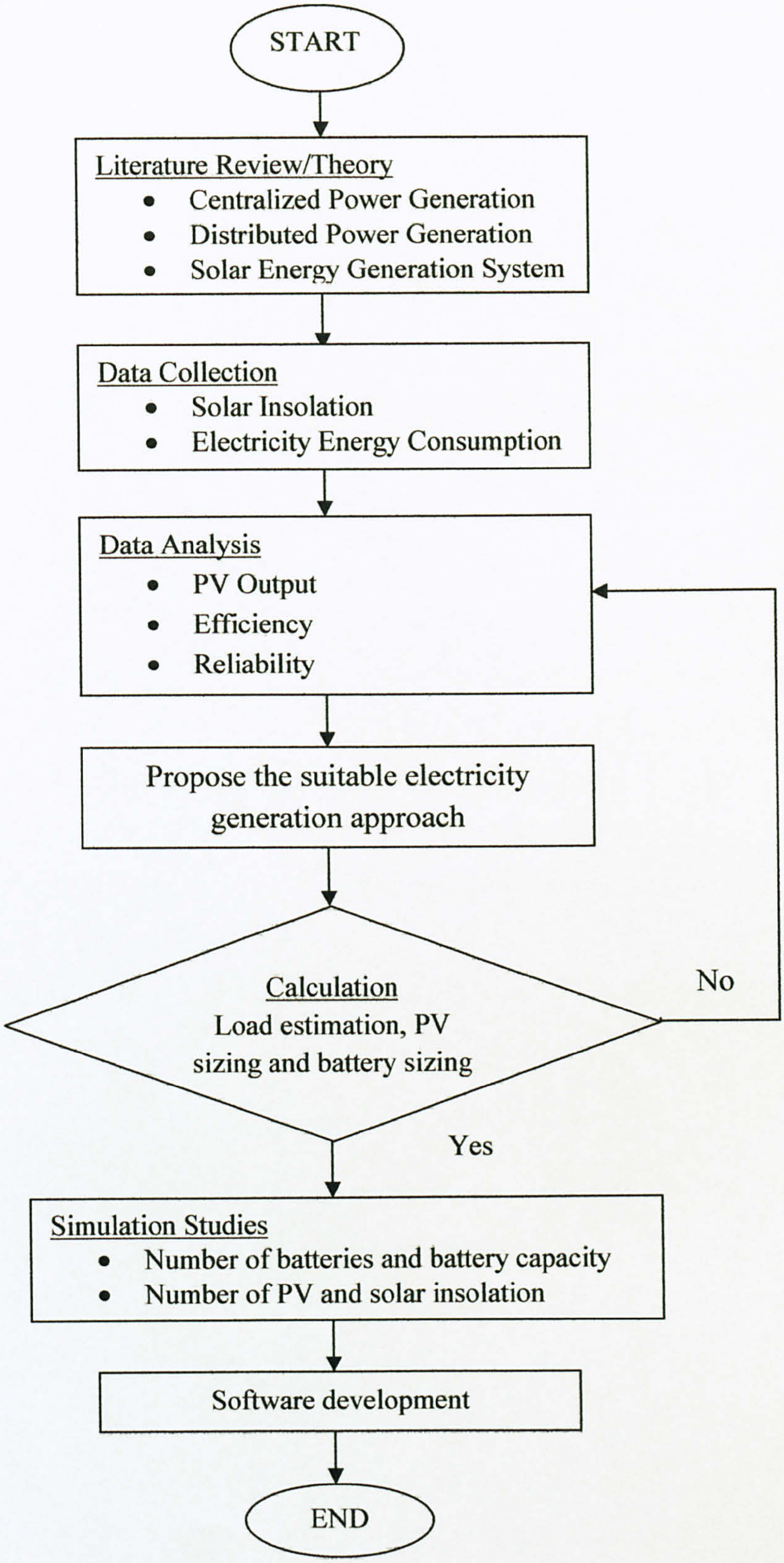

Figure 6: Flow chart for procedure identification.

3.2 Tools and Equipment Required

3.2.1 Pyranometer

Pyranometer is an instrument for measuring total radiation which includes beam radiation and diffuse radiation. The detector for this instrument must have a response independent of wavelength of radiation over the solar energy spectrum [16]. The pyranometer is used during the measurement of solar insolation at Putrajaya.

3.2.2 Kipp & Zonen METEON

Kipp and Zonen METEON is a high performance sensor readout unit with integrated data logger. It is a handheld readout unit which must be connected to the pyranometer. Use of the data logger functions and programming the sensor sensitivity is done with the USB interface which is to connect the METEON to a PC [17].

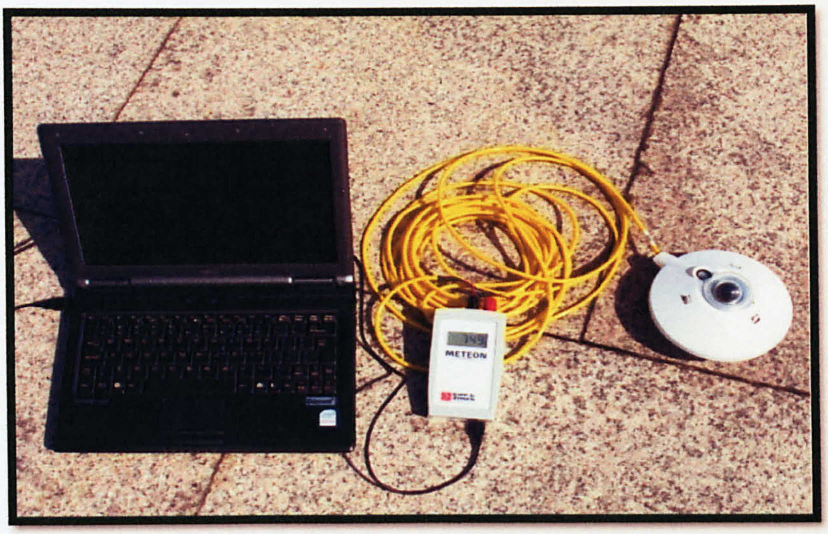

Figure 7: Connection of pyranometer, data logger and PC for the solar insolation measurement.

3.3.1 Microsoft Excel

Microsoft Excel is the software used to perform mathematical models and analysis of the input and output of the system. The PV sizing and battery bank sizing is calculated and compiled using Microsoft Excel. The relationship of 'PV module and solar insolation' and 'batteries and battery capacity' has been obtained based on the mathematical modeling programmed to the Microsoft Excel.

3.2.3 Microsoft Visual Basic 2008

Visual Basic is the software used to design an interface for the PV based electrical power generation system. Visual Basic enables the rapid application development (RAD) of graphical user interface (GUI) applications, access to databases using Data Access Objects, Remote Data Objects, or ActiveX Data Objects, and creation of ActiveX controls and objects [18]. A user interface software has been developed using Visual Basic which are includes load estimation, efficiency estimation, battery bank sizing, PV array sizing and outcome for the complete system.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Power Generation Concept

There are two types of electricity generation system which are centralized power generation and distributed power generation. After analyzing the characteristic of both generation concepts, the chosen concept is the distributed power generation system.

The distance of power plant becomes nearer in distributed power generation. This concept avoiding the long transmission line which is one of the characteristics of centralized power plant that caused the power dissipated. Distributed power generation concept was chosen because it is suitable to be implemented in the PV based electrical power generation. Figure 8 shows the design concept of PV based electrical power generation which implements the distributed power generation approach.

The electricity is generated using PV system and auxiliary generator. Auxiliary generator will operate when the solar insolation is low during the rainy or cloudy days. Energy generated by the PV system is also being stored in the battery for the usage of electricity during night time. The distribution stage started with controller unit which consists of power controller, charge controller and inverter. The function of power controller is to select the input of the system which is from PV power plant or auxiliary generator. The function of controller is to maintain batteries at highest level of charge while protecting against overcharging by the PV array and from over discharge by the load. The inverter is used to convert the electricity in PV based electrical power generation system from DC into AC power. In this report, a residential area with 20 houses is considered as the consumer of PV based electrical power generation system.

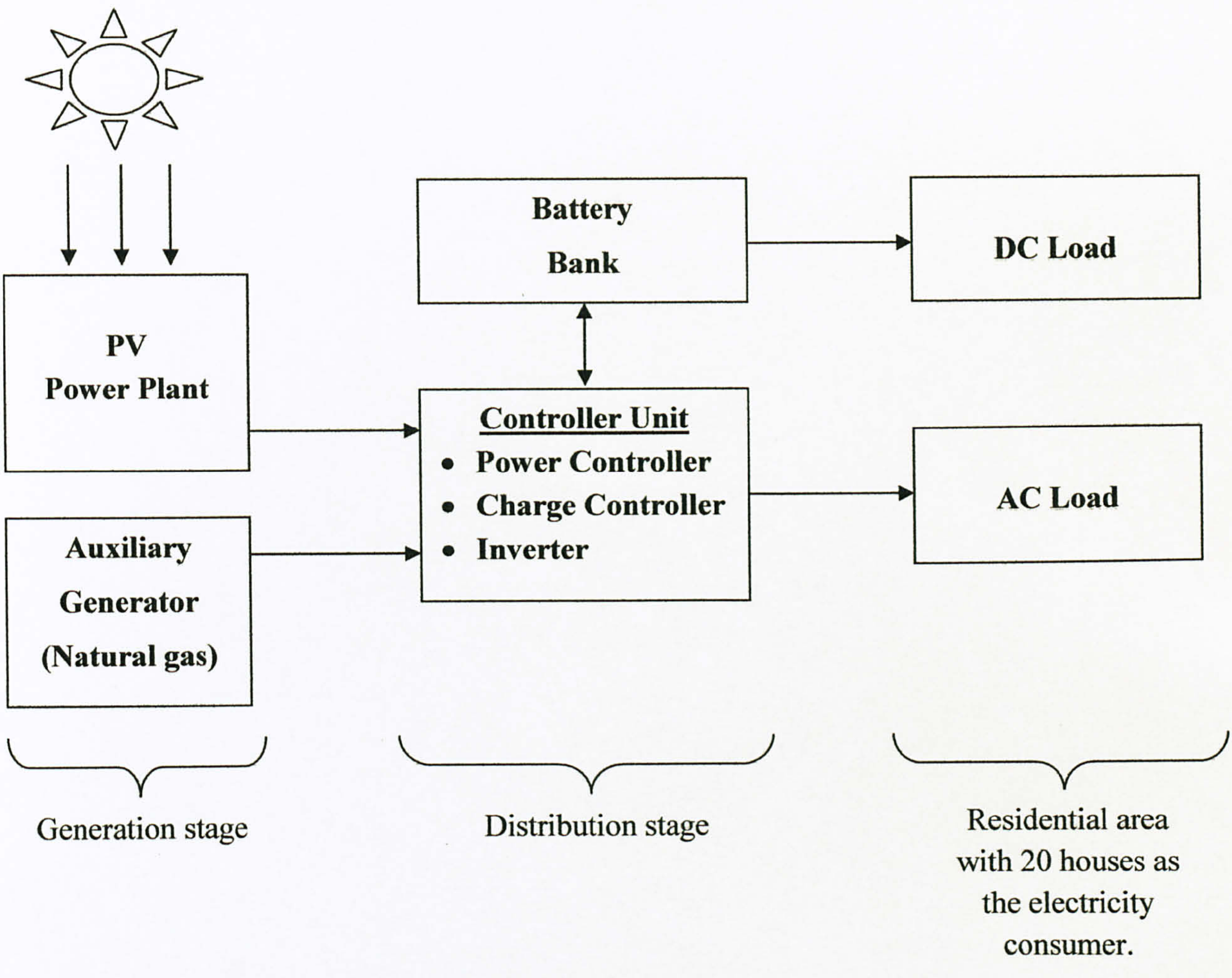

Figure 8: Design concept of PV based electrical power generation.

4.2 Sizing Calculation

Firstly, electrical load requirement needs to be determined. Then, the battery storage capacity is calculated to be able to independently supply the loads for a certain time if cloudy or rainy weather reduces the array output. Finally, the PV array is sized to produce enough electrical power to meet the load requirement. Figure 9 shows the stages of sizing calculation.

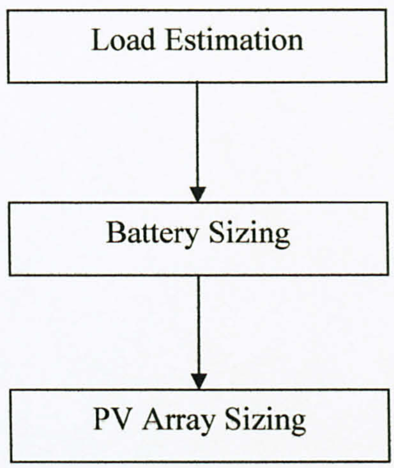

Figure 9: Stage of sizing calculation.

4.2.1 Load Estimation

The electrical loads analysis is a very important step in PV system sizing. The power demand determined is the amount of electricity that must be produced. Underestimating loads will result in a system that is too small and not able to supply enough energy to the loads while overestimating loads will result in a larger system which is expensive to be implemented. The load estimation method used in this report is based on the collection of Tenaga Nasional Berhad (TNB) electric bills for various types of houses in Malaysia. The load obtained is the summation of AC and DC loads. Thirty samples of electricity usage have been collected to calculate the average value of load to be used as load reference value in PV sizing and battery sizing. The electrical energy consumption of the houses is tabulated in Table 4.

$$\text{Average} = \frac{10876\text{kWh}}{30}$$

$$= 363 \text{ kWh in a month}$$

$$= 12 \text{ kWh in a day}$$

From the load estimation calculation above, the average electricity consumed in a month is 363kWh. As stated in the power generation section, a residential area with 20 houses is considered as the consumer. The electrical power needed in a month for the residential area is:

$$= 363 \text{ kWh x } 20$$
$$= 7260 \text{ kWh}$$

The watt hours per day:

$$= 242 \text{ kWh/day}$$

The load for the residential area is in AC. Therefore, the inverter must be considered in the calculation because the output of the PV system is in DC.

Assume the inverter efficiency = 0.85

Then, $\dfrac{242\,\text{kWh}}{0.85} = 285\,\text{kWh}$

The PV based electrical power generation also considered to use auxiliary generator in case of electricity shortage due to low solar insolation. For this project, 30% of the electricity is considered from the auxiliary generator. Another 70% of the electricity is generated from PV power plant which is 200kWh. The battery array sizing and PV array sizing is based on this value. The 24V system voltage and 2 days of autonomy will be used in this project.

Table 4: Electrical Energy Consumption

House – (Type of house)	Electrical Energy Usage (kWh)
1 - (Double storey)	828
2 - (Double storey)	280
3 - (Single storey)	264
4 - (Single storey)	207
5 - (Double storey)	586
6 - (Double storey)	582
7 - (Single storey)	453
8 - (Single storey)	409
9 - (Single storey)	394
10 - (Double storey)	416
11 - (Single storey)	152
12 - (Single storey)	359
13 - (Single storey)	245
14 - (Single storey)	280
15 - (Double storey)	451
16 - (Double storey)	324
17 - (Single storey)	193
18 - (Double storey)	472
19 - (Double storey)	338
20 - (Single storey)	242
21 - (Single storey)	185
22 - (Single storey)	408
23 - (Double storey)	529
24 - (Double storey)	247
25 - (Single storey)	176
26 - (Double storey)	429
27 - (Single storey)	168
28 - (Double storey)	411
29 - (Double storey)	396
30 - (Double storey)	452
Total electrical energy consumption for 30 houses	**10876**

4.2.2 Battery Storage Sizing

The function of batteries is to store energy produce from the PV array during high insolation and supply the electrical energy to the loads during cloudy weather which have low insolation and at night time [19]. Batteries for the PV system need to properly size because the capacity of the storage must meet the load requirement for the desired autonomy period.

The battery storage capacity is determined using the following formula:

$$B_{out} = \frac{E_{crit} \times t_a}{V_{SDC}} \tag{1}$$

where,
B_{out} = required battery bank output (A-h)
E_{crit} = daily electrical energy consumption (Wh/day)
t_a = autonomy (days)
V_{SDC} = nominal DC system voltage (V)

Table 5: Battery specification [Appendix III]

Type	Vision 6FM200D
Manufacturer	Vision Battery
Nominal capacity	200 Ah
Nominal voltage	12V
Efficiency	80%
Float life	10 years

$$B_{out} = \frac{200 \text{ kWh x } 2}{24V}$$

$$= 16\ 667 \text{ Ah}$$

$$\frac{16667 \text{ Ah}}{200 \text{ Ah}} = 84 \text{ unit of batteries}$$

Thus, 84 units of batteries need by the system to support the load for two days of autonomy.

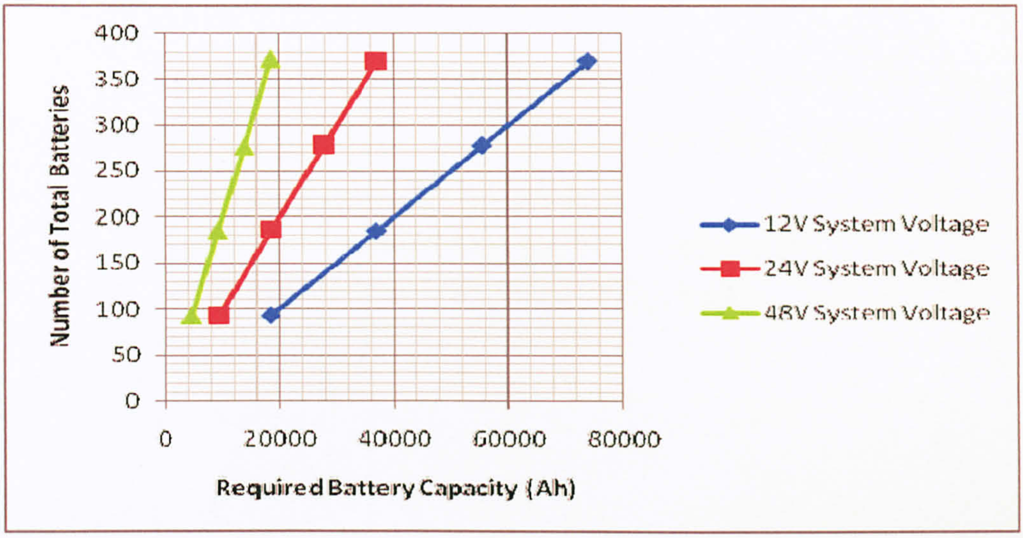

Figure 10: Relationship between number of batteries and required battery capacity (Ah).

Based on the graph above, smaller system voltage requires higher battery capacity; the number of batteries is increased. As the number of battery increased, the cost of installation is increased and the large area for battery bank is required. Therefore, the correct sizing of battery bank needs to determine to get the balance of system. The four points at each line also indicates the day of autonomy from one to four. Number of battery required increased based on the number of autonomy day selected. A battery sizing spreadsheet is attached in Appendix V.

4.2.3 PV Array Sizing

The array is needed to produce enough electrical energy and the sizing is important to know the capacity of PV modules required to meet the load requirement.

Table 6: PV Module Specification [Appendix IV]

Type	SHARP NU – U230F3
Efficiency	14.1%
Voltage	30.0V
Current	7.67
Area	1.64m x 0.994m

Area of PV array can be calculated using the following formula:

$$\text{Area of PV array } (\text{m}^2) = \frac{\text{Output (kW)}}{\text{Efficiency(\%) x Input} \left(\frac{\text{kW}}{\text{m}^2}\right)} \quad (2)$$

Output = 200kW

Efficiency = 14.1%

Input = 570.6 W/m^2 (Putrajaya Solar Radiation, refer Appendix II)

$$\text{Area of PV Array } (\text{m}^2) = \frac{200\text{kWh}}{0.141 \text{ x } 0.5706\text{kW/m}^2} = 2486\text{m}^2$$

$$= 2486\text{m}^2$$

$$\frac{\text{Area of PV Array } (\text{m}^2)}{\text{Area of PV Module } (\text{m}^2)} = \frac{2486\text{m}^2}{1.63\text{m}^2} \approx 1526 \text{ units of PV module}$$

$$\frac{\text{Output of PV Array (kW)}}{\text{Units of PV Module}} = \frac{200\text{kW}}{1526 \text{ units}} = 131\text{W per module}$$

From the result obtained, the area of PV array is 2486 . It is equivalent to 0.2486 Hectares of land needed to install the PV. Area of PV array is depends on the efficiency of PV. In other words, as the efficiency of PV increase, the area of PV array decrease. It is shows in the figure 11:

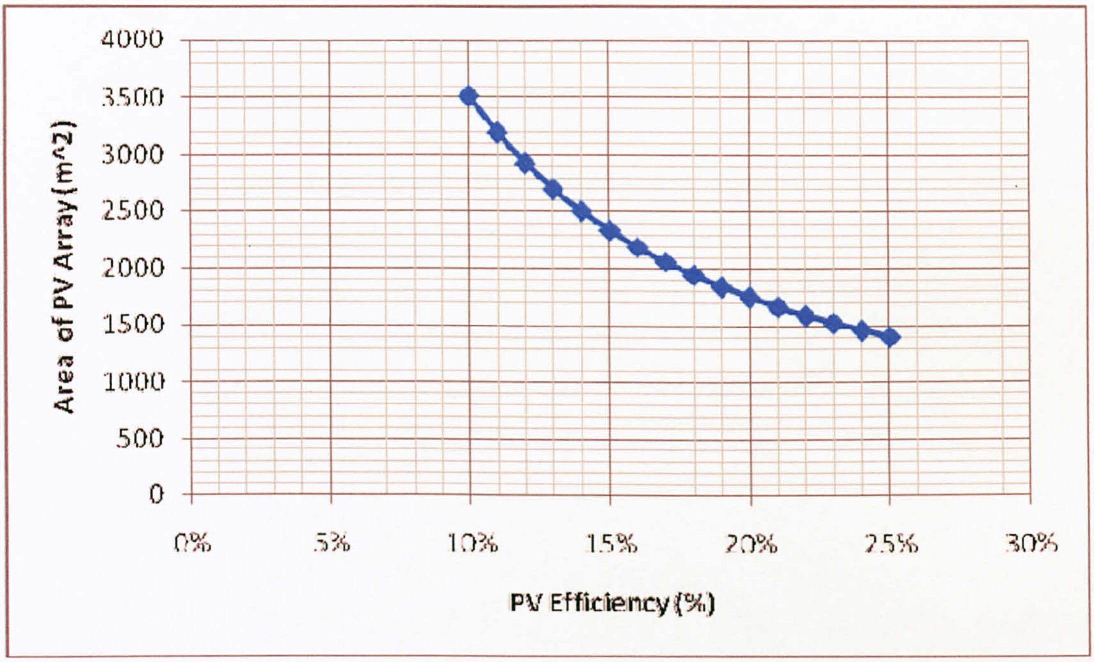

Figure 11: Relationship between area of PV array and PV efficiency.

The following graph shows the relationship between numbers of PV module required and solar radiation. The solar radiation data was measured in Putrajaya. The mathematical modeling is done with the same amount of load which is the daily energy consumption calculated in the load estimation section. A PV sizing spreadsheet is attached in Appendix VI.

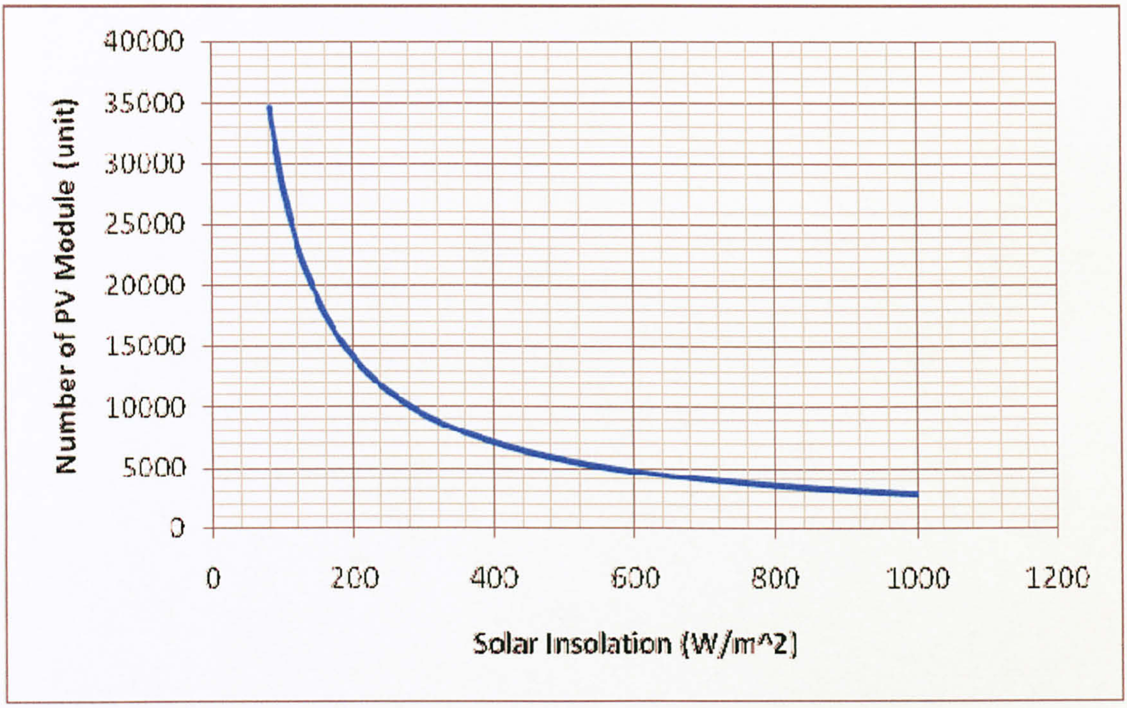

Figure 12: Relationship between number of PV module and solar radiation (W/m2)

Based on the graph above, it shows that the higher amount of solar insolation, the number of PV module required is decreased. Energy output of PV module affected by the amount of solar radiation. The output of PV array changes with the coordination of sun. Figure 13 shows the solar radiation with respect to the times.

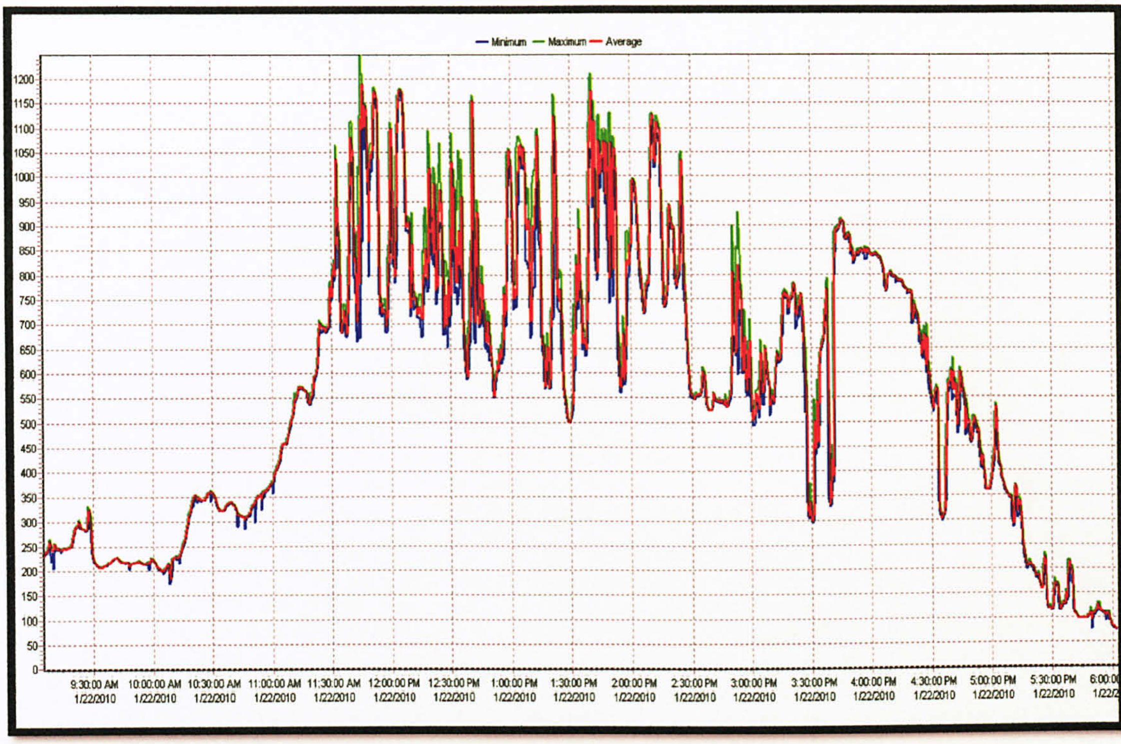

Figure 13: Relationship between solar insolation and time

4.2.4 PV System Calculator

The PV System Calculator is software developed using Microsoft Visual Basic 2008 to assist the user in calculating the load estimation, efficiency estimation, battery bank sizing and PV array sizing. Sizing calculation is very important in developing PV based Electrical Power Generation because it will determine the most feasible system with the required output. Thus, the installation cost of the system could be minimized.

This software consists of four interfaces which are load estimation, efficiency estimation, battery bank sizing and PV array sizing. In each interface, the user need to fill in the required value of all parameters in order to determined the results [20]. After all four interface obtained its result, the last interface will come out with the complete PV based Electrical Power Generation requirement stated.

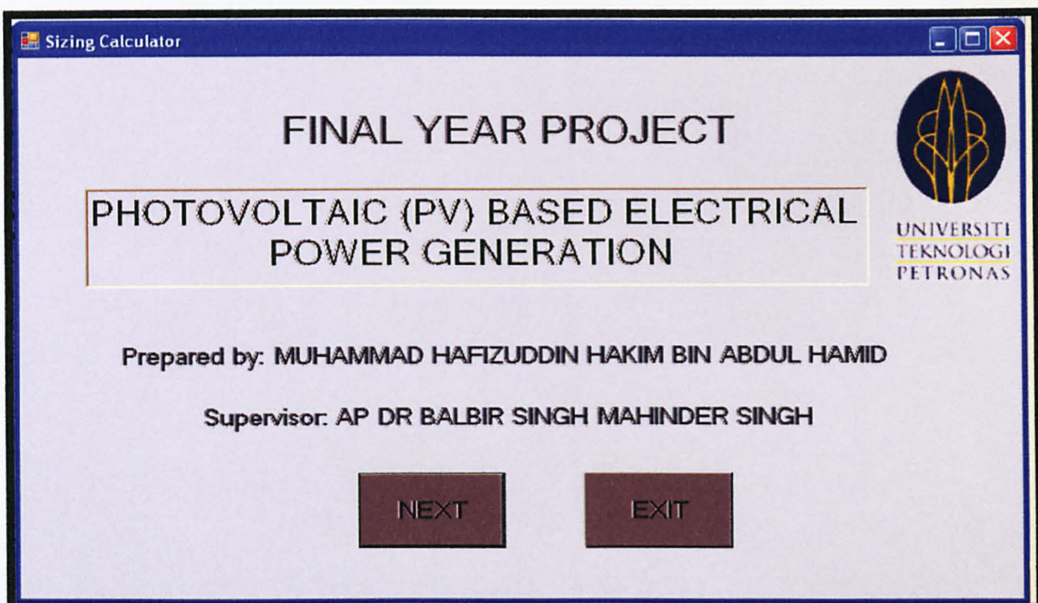

Figure 14: PV System Calculator main page

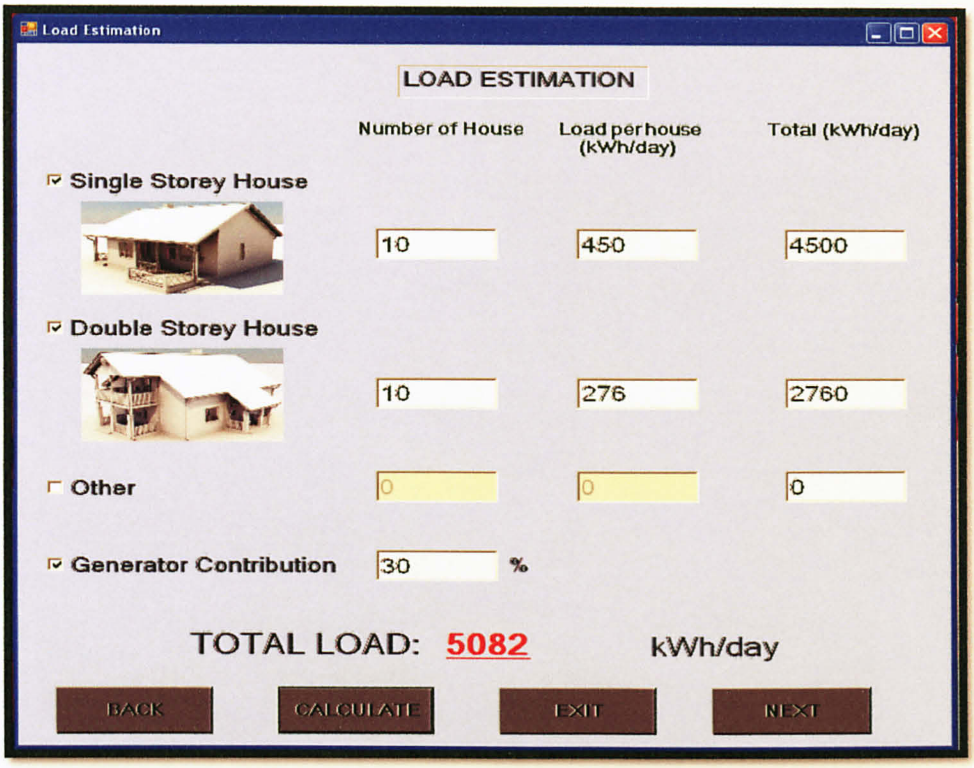

Figure 15: Load estimation interface.

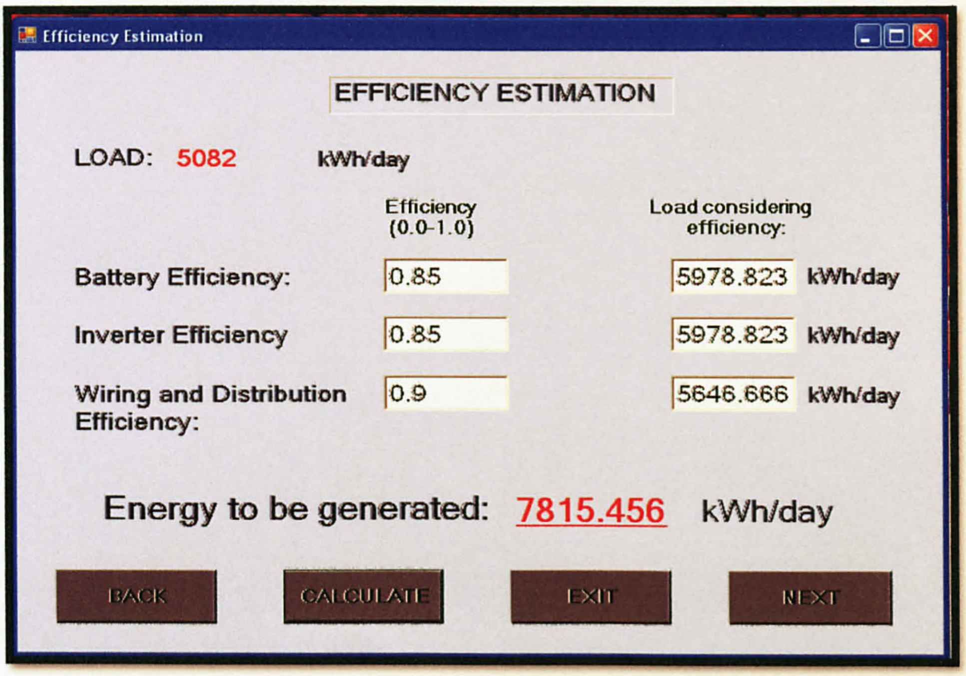

Figure 16: Efficiency estimation interface.

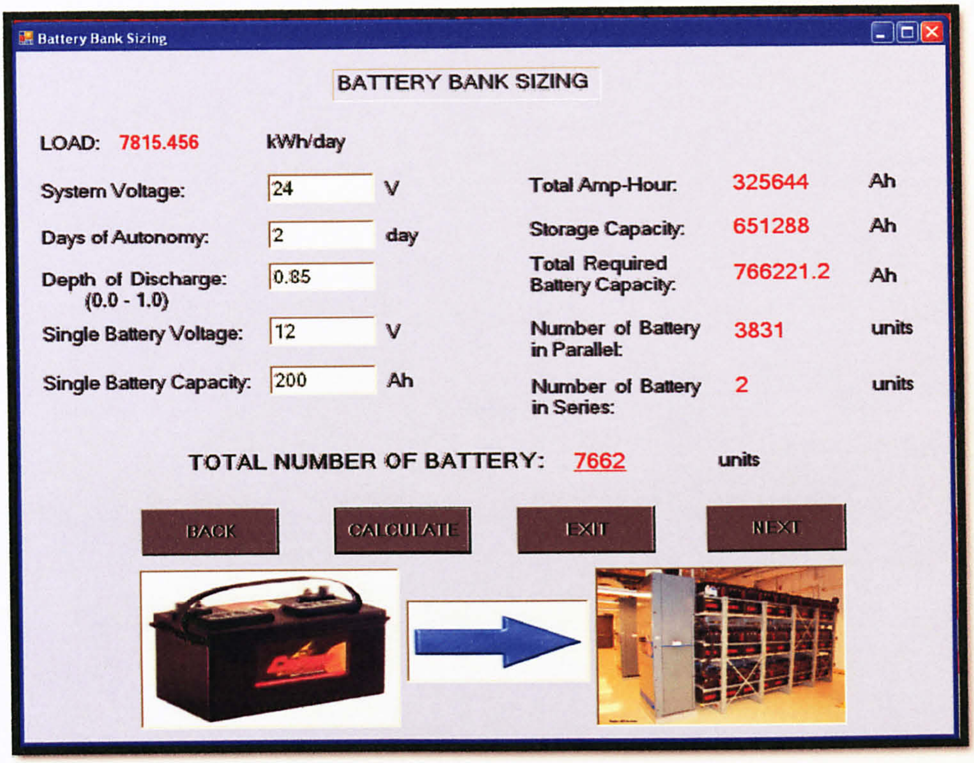

Figure 17: Batter bank sizing interface

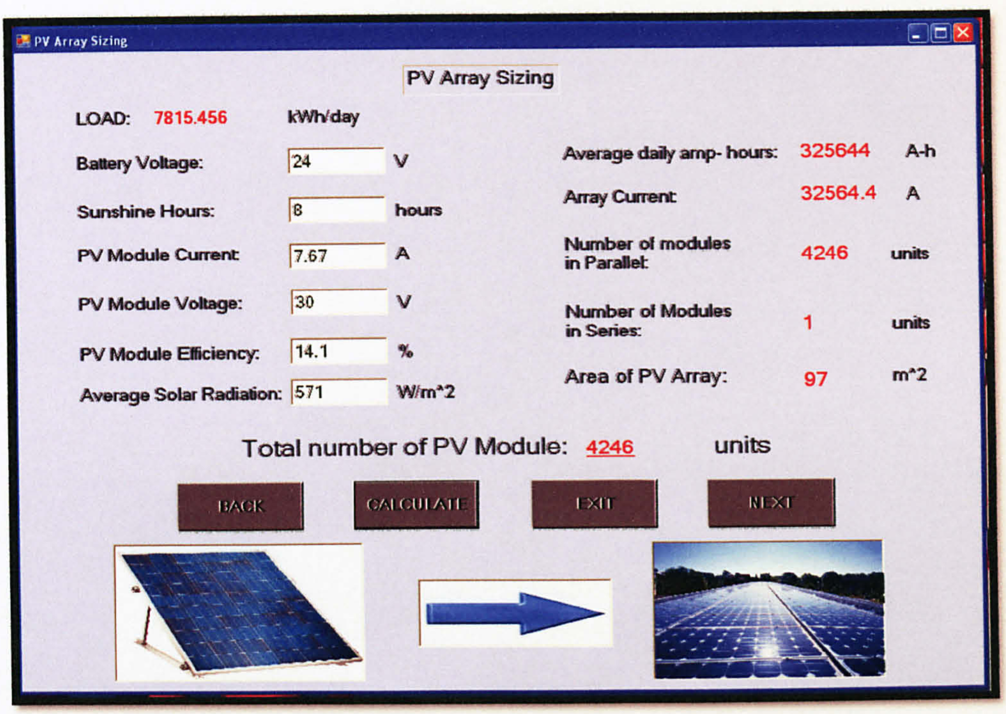

Figure 18: PV array sizing interface

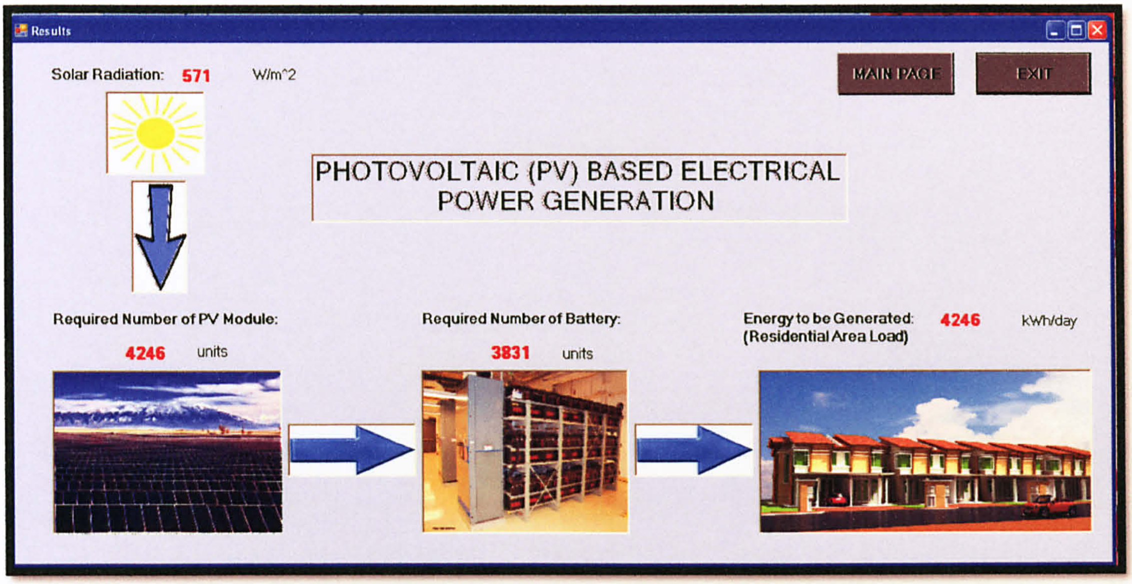

Figure 19: Outcome that can be used for implementation.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, this project was successfully conducted as it achieved all the objectives that were set forth. The distributed power generation has been chosen as the suitable power generation system approach in this project. It is integrate the PV based electricity generating system with distributed generating approach. This integration system could reduce the electricity transmission losses because the electricity is generated near to the customer. Other than that, it could reduce the consumption and dependence of natural gas as fuel for current electricity generating scheme. This project allowed the feasibility studies of the implementing PV based electrical power generation in Malaysia. A mathematical model that developed in this project is required to obtain the relationship of solar insolation, number of PV, number of batteries and the area of PV array. The development of software for PV based electrical power generation system was successfully done. The purpose of the software is to guide user to size the PV system. It is important to avoid oversize or undersize the system which will increase the installation cost and could affect the performance and the efficiency of the system. Therefore, this project is beneficial to the country in developing renewable energy technology.

5.2 Recommendation

For project enhancement, a few changes to the PV based electrical power generation system can be made. One of it is the integration of the system with other renewable energy source such as wind energy, solar thermal and biomass. The hybrid generation could increase the output of the system. This development will help to intensify the use of renewable energy efficiently. Integrated hybrid system will improve energy efficiency, energy conservation as well as promoting to reduce the pollution caused by fossil fuel power generation system. Figure 20 illustrates the integrated hybrid system. Improvement to the project also can be done to the software because the integrated hybrid system has several sources. Therefore, all the sizing parameter of renewable energy source must be included in order to size a complete integrated hybrid system.

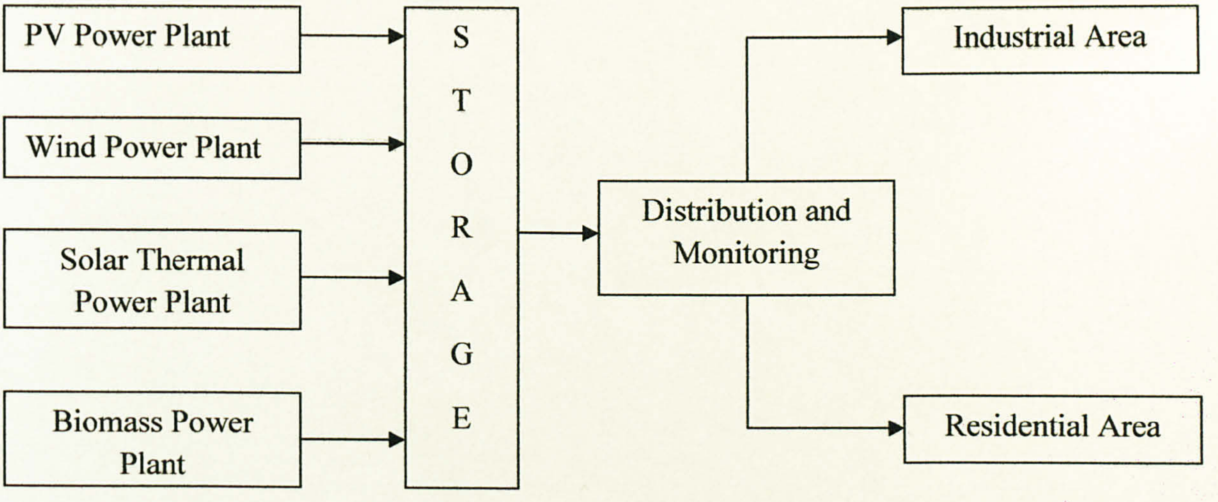

Figure 20: Integrated Hybrid System

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APPENDICES

APPENDIX 1

GANTT CHART

Final Year Project 1 July 2009

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	Mid Semester Break	10	11	12	13	14
1	Selection of Project Topic															
2	Preliminary Research Work															
3	Submission of Preliminary Report															
4	Seminar 1 (optional)															
5	Project Work															
6	Submission of Progress Report															
7	Seminar 2 (compulsory)															
8	Project work continues															
9	Submission of Interim Report Final Draft															
10	Oral Presentation															

Suggested milestone

Process

APPENDIX 1

GANTT CHART

Final Year Project 2 Jan 2010

No.	Detail/ Week	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14
1	Project Work Continue															
2	Submission of Progress Report 1															
3	Project Work Continue															
4	Submission of Progress Report 2															
5	Seminar (compulsory)															
5	Project work continue															
6	Poster Exhibition															
7	Submission of Dissertation (soft bound)															
8	Oral Presentation															
9	Submission of Project Dissertation (Hard Bound)															

Suggested milestone

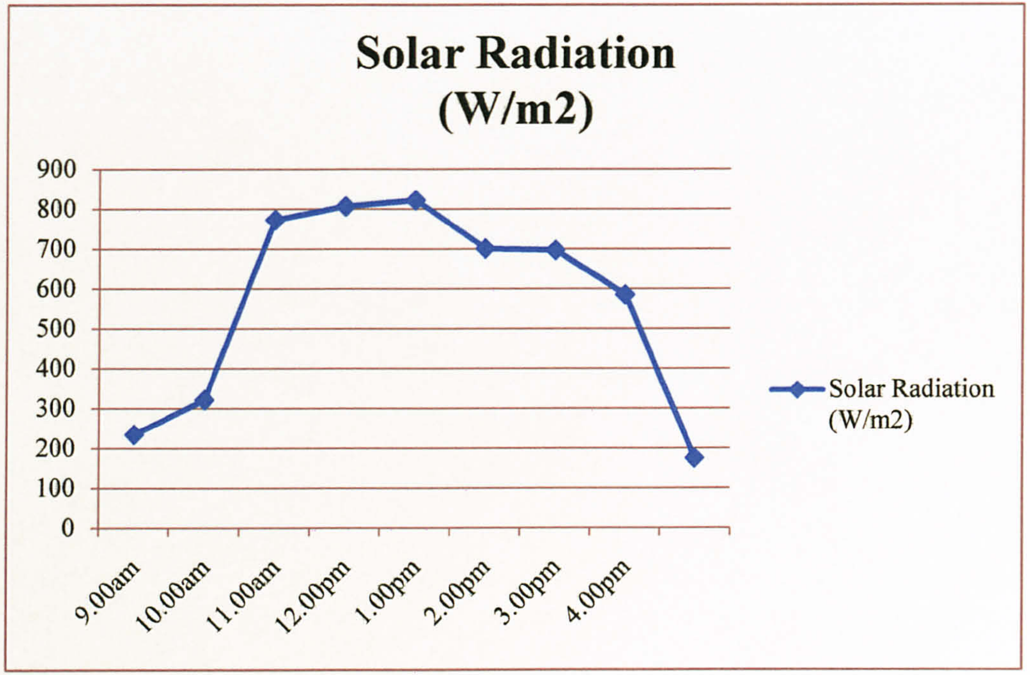
Process

APPENDIX II

PUTRAJAYA SOLAR RADIATION DATA

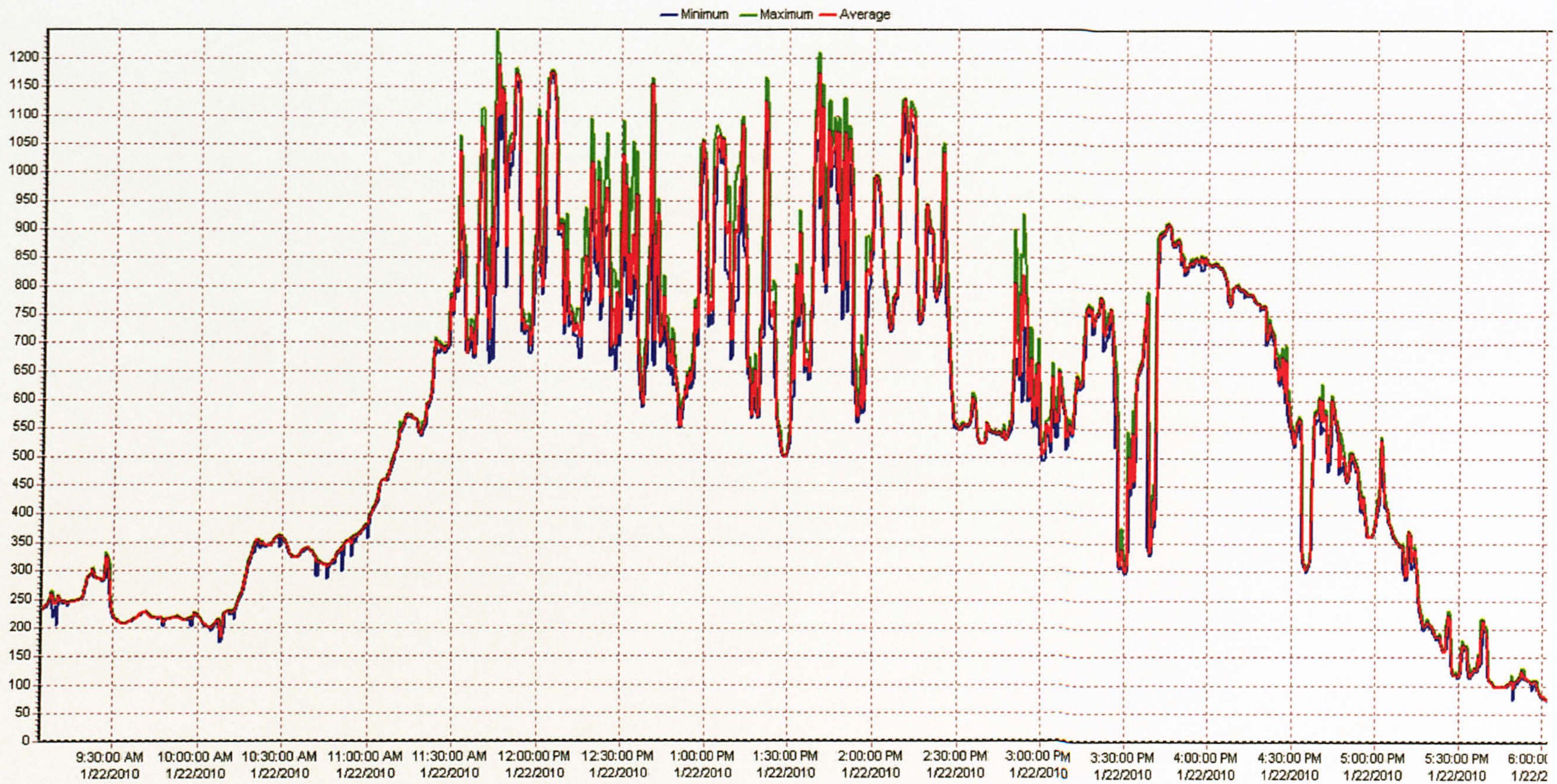
(MEASURED ON 22nd JANUARY 2010)

Time	Solar Radiation (W/m2)
9.00am	234.8417
10.00am	322.0583
11.00am	773.1167
12.00pm	806.8333
1.00pm	822.1917
2.00pm	700.95
3.00pm	697.2083
4.00pm	585.5
5.00pm	176.1478



Average Solar Radiation: 570.587 W/m^2
Maximum at 1.00pm – 2.00pm: 822.1917 W/m^2
Minimum at 5.00pm – 6.00pm: 176.1478 W/m^2

PUTRAJAYA SOLAR RADIATION DATA
(MEASURED ON 22nd JANUARY 2010)



APPENDIX III

BATTERY SPECIFICATIONS

6FM200D *12V 200Ah(10hr)*

The rechargeable batteries are lead-lead dioxide systems. The dilute sulfuric acid electrolyte is absorbed by separators and plates and thus immobilized. Should the battery be accidentally overcharged producing hydrogen and oxygen, special one-way valves allow the gases to escape thus avoiding excessive pressure build-up. Otherwise, the battery is completely sealed and is, therefore, maintenance-free, leak proof and usable in any position.

Battery Construction

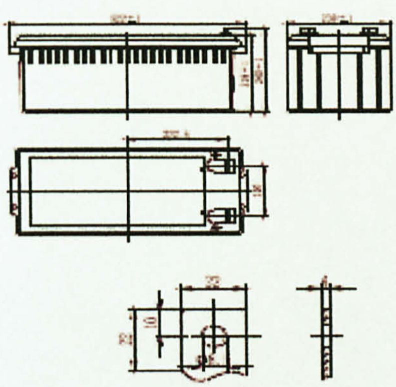
Component	Positive plate	Negative plate	Container	Cover	Safety valve	Terminal	Seperator	Electrolyte
Raw material	Lead dioxide	Lead	ABS	ABS	Rubber	Copper	Fiberglass	Sulfuric acid

General Features

- Absorbent Glass Mat (AGM) technology for efficient gas recombination of up to 99% and freedom from electrolyte maintenance or water adding.
- Not restricted for air transport-complies with IATA/ICAO Special Provision A67.
- UL-recognized component.
- Can be mounted in any orientation.
- Computer designed lead, calcium tin alloy grid for high power density.
- Long service life, float or cyclic applications.
- Maintenance-free operation.
- Low self discharge.

Dimensions and Weight

Length(mm / inch) .... 522 / 20.55
Width(mm / inch) .... 238 / 9.37
Height(mm / inch) .... 218 / 8.58
Total Height(mm / inch) .... 240 / 9.45
Approx. Weight(Kg / lbs) .... 65 / 143.3



Performance Characteristics

Nominal Voltage 12V
Number of cell 6
Design Life .... 10 years
Nominal Capacity 77°F(25°C)
10 hour rate (20.0A, 10.8V) 200Ah
5 hour rate (35.8A, 10.5V) 179.0Ah
1 hour rate (126A, 9.6V) 126Ah
Internal Resistance
Fully Charged battery 77°F(25°C) 3.5mOhms
Self-Discharge
3% of capacity declined per month at 20°C(average)
Operating Temperature Range
Discharge .... -20~60°C
Charge .... -10~60°C
Storage .... -20~60°C
Max. Discharge Current 77°F(25°C) .... 1000A(5s)
Short Circuit Current 3300A
Charge Methods: Constant Voltage Charge 77°F(25°C)
Cycle use 14.4-14.7V
Maximum charging current 60A
Temperature compensation .... -30mV/°C
Standby use 13.6-13.8V
Temperature compensation .... -20mV/°C

Discharge Constant Current (Amperes at 77°F25°C)

End Point Volts/Cell	5min	10min	15min	30min	45min	1h	3h	5h	10h
1.60V	517	424	350	215	156	126	57.0	38.0	20.4
1.65V	489	403	340	207	150	122	55.0	37.0	20.3
1.70V	479	385	327	201	146	118	54.5	36.4	20.2
1.75V	439	367	310	195	142	115	52.9	35.8	20.1
1.80V	408	318	281	182	137	112	50.5	35.2	20.0

Discharge Constant Power (Watts at 77°F25°C)

End Point Volts/Cell	5min	10min	15min	30min	45min	1h	2h	3h	5h
1.60V	935	727	607	402	288	227	147	108	72.6
1.65V	856	701	586	380	280	222	145	106	71.6
1.70V	816	677	569	378	274	218	142	104	70.8
1.75V	774	654	561	363	259	214	128	100	69.9
1.80V	737	619	548	355	245	212	125	97.0	69.0

(Note)The above characteristics data are average values obtained within three charge/discharge cycles not the minimum values.

 www.vision-batt.com

APPENDIX IV

PV MODULE SPECIFICATIONS

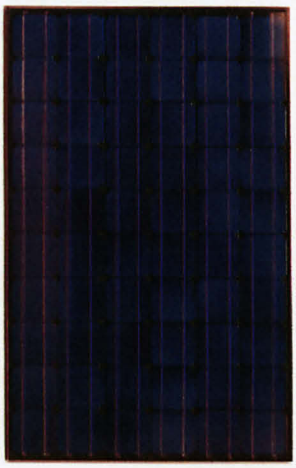
SHARP.

solar electricity

230 WATT

RESIDENTIAL MODULE

NEC 2008 Compliant



NU-U230F3

RESIDENTIAL 230 WATT MODULE FROM THE WORLD'S TRUSTED SOURCE FOR SOLAR.

Our most powerful residential module manufactured today, the NU-U230F3 blends high performance with advanced solar aesthetics. Black backsheet and sleek black frame create a modern silhouette on nearly any roof. Using breakthrough technology, made possible by nearly 50 years of proprietary research and development, this module incorporates an advanced surface texturing process to increase light absorption and improve efficiency. Flexible enough to permit installation on nearly any kind of roof, the 230 watt module is the newest innovation in Sharp's residential product offerings.

Sharp's highest-power residential solar module makes a beautiful addition to nearly any roof.

ENGINEERING EXCELLENCE
NU-U230F3 is the perfect combination of high-performance and design.

ADVANCED AESTHETICS
Sleek, black frame module provides an elegant appearance that blends beautifully with your home's roofline.

DURABLE
Tempered glass, EVA lamination and weatherproof backskin provide long-life and enhanced cell performance.

RELIABLE
25-year limited warranty on power output.

HIGH PERFORMANCE
This module uses an advanced surface texturing process to increase light absorption and improve efficiency.

Black frame improves aesthetics for residential roof top applications

Laminated glass construction in a high torsion frame

SHARP: THE NAME TO TRUST
When you choose Sharp, you get more than well-engineered products. You also get Sharp's proven reliability, outstanding customer service and the assurance of our 25-year limited warranty on power output. A global leader in solar electricity, Sharp powers more homes and businesses than any other solar manufacturer worldwide.

BECOME POWERFUL

230 WATT

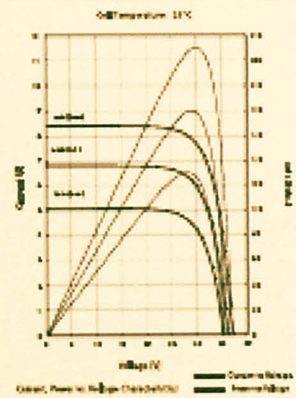
NU-U230F3

NEC 2008 Compliant
Module output cables 12 AWG with locking connectors

ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)*	230 W
Tolerance of Pmax	+10%/-5%
Type of Cell	Monocrystalline silicon
Cell Configuration	60 in series
Open Circuit Voltage (Voc)	37.0 V
Maximum Power Voltage (Vpm)	30.0 V
Short Circuit Current (Isc)	8.40 A
Maximum Power Current (Ipm)	7.67 A
Module Efficiency (%)	14.1%
Maximum System (DC) Voltage	600 V
Series Fuse Rating	15 A
NOCT	47.5°C
Temperature Coefficient (Pmax)	-0.485%/°C
Temperature Coefficient (Voc)	-0.351%/°C
Temperature Coefficient (Isc)	0.053%/°C

*Measured at (STC) Standard Test Conditions: 25°C, 1 kW/m² insolation, AM 1.5

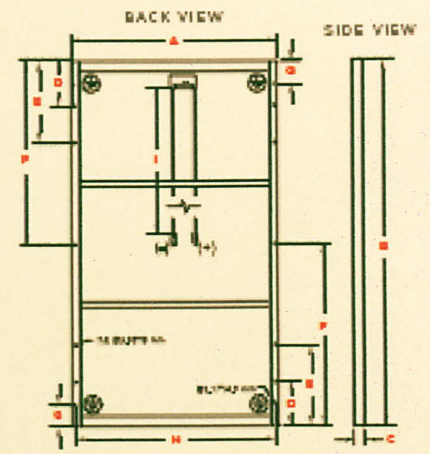
IV CURVES



MECHANICAL CHARACTERISTICS	
Dimensions (A x B x C below)	39.1" x 64.6" x 1.8"/994 x 1640 x 46 mm
Cable Length (I)	43.3"/1100 mm
Output Interconnect Cable**	12 AWG with MC4 Locking Connector
Weight	44.1 lbs / 20.0 kg
Max Load	50 psf (2400 Pascals)
Operating Temperature (cell)	-40 to 194°F / -40 to 90°C

**A safety lock clip (Multi Contact part number PV-SSH4) may be required in readily accessible locations per NEC 2008 690.33 (C)

DIMENSIONS



Contact Sharp for tolerance specifications

QUALIFICATIONS	
UL Listed	UL 1703
Fire Rating	Class C

WARRANTY
25-year limited warranty on power output
Contact Sharp for complete warranty information

Design and specifications are subject to change without notice.
Sharp is a registered trademark of Sharp Corporation. All other trademarks are property of their respective owners. Contact Sharp to obtain the latest product manuals before using any Sharp device.

SHARP ELECTRONICS CORPORATION
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www.sharpusa.com/solar

SSF-840 - PC-06-09

APPENDIX V

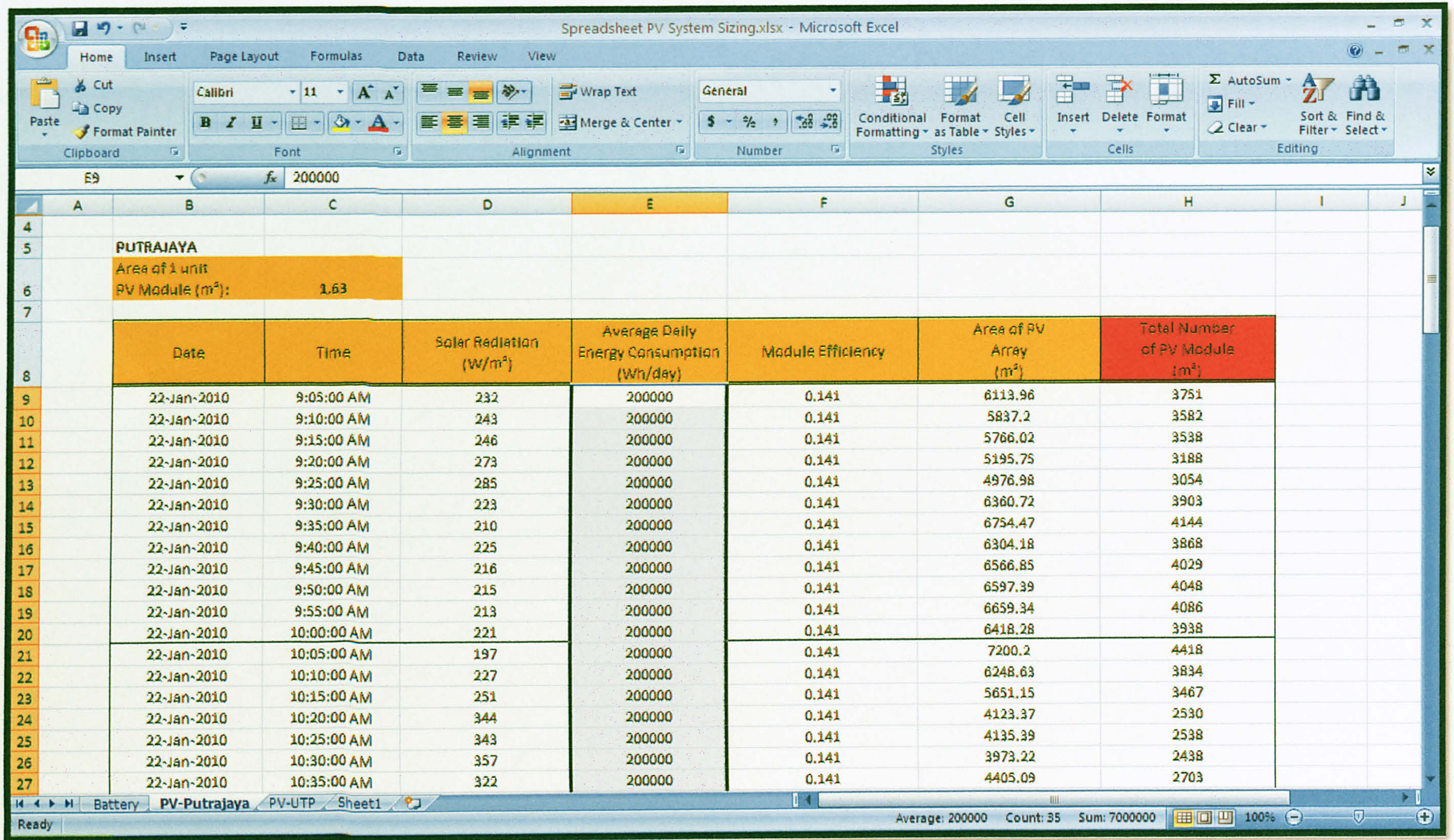
BATTER BANK SIZING SPREADSHEET

BATTERY BANK SIZING

Average Daily Energy Consumption (Wh/day)	DC System Voltage (Vdc)	Amp-Hour Load (A-h/day)	Autonomy (days)	DOD	Required Battery Capacity (A-h)	Capacity of Selected Battery (A-h)	Batteries in Parallel	Nominal Battery Voltage (V)	Batteries in Series	Total Batteries	System Battery Capacity (A-h)	Usable Battery Capacity (A-h)
200000	12	16666.66667	1	0.9	18518.52	200	93	12	1	93	18600	16740
200000	12	16666.66667	2	0.9	37037.04	200	185	12	1	185	37000	33300
200000	12	16666.66667	3	0.9	55555.56	200	278	12	1	278	55600	50040
200000	12	16666.66667	4	0.9	74074.07	200	370	12	1	370	74000	66600
200000	24	8333.333333	1	0.9	9259.26	200	46	12	2	92	9200	8280
200000	24	8333.333333	2	0.9	18518.52	200	93	12	2	186	18600	16740
200000	24	8333.333333	3	0.9	27777.78	200	139	12	2	278	27800	25020
200000	24	8333.333333	4	0.9	37037.04	200	185	12	2	370	37000	33300
200000	48	4166.666667	1	0.9	4629.63	200	23	12	4	92	4600	4140
200000	48	4166.666667	2	0.9	9259.26	200	46	12	4	184	9200	8280
200000	48	4166.666667	3	0.9	13888.89	200	69	12	4	276	13800	12420
200000	48	4166.666667	4	0.9	18518.52	200	93	12	4	372	18600	16740

APPENDIX VI

PV ARRAY SIZING SPREADSHEET



PUTRAJAYA

Area of 1 unit PV Module (m^2): 1.63

Date	Time	Solar Radiation (W/m^2)	Average Daily Energy Consumption (Wh/day)	Module Efficiency	Area of PV Array (m^2)	Total Number of PV Module (m^2)
22-Jan-2010	9:05:00 AM	232	200000	0.141	6113.96	3751
22-Jan-2010	9:10:00 AM	243	200000	0.141	5837.2	3582
22-Jan-2010	9:15:00 AM	246	200000	0.141	5766.02	3538
22-Jan-2010	9:20:00 AM	273	200000	0.141	5195.75	3188
22-Jan-2010	9:25:00 AM	285	200000	0.141	4976.98	3054
22-Jan-2010	9:30:00 AM	223	200000	0.141	6360.72	3903
22-Jan-2010	9:35:00 AM	210	200000	0.141	6754.47	4144
22-Jan-2010	9:40:00 AM	225	200000	0.141	6304.18	3868
22-Jan-2010	9:45:00 AM	216	200000	0.141	6566.85	4029
22-Jan-2010	9:50:00 AM	215	200000	0.141	6597.39	4048
22-Jan-2010	9:55:00 AM	213	200000	0.141	6659.34	4086
22-Jan-2010	10:00:00 AM	221	200000	0.141	6418.28	3938
22-Jan-2010	10:05:00 AM	197	200000	0.141	7200.2	4418
22-Jan-2010	10:10:00 AM	227	200000	0.141	6248.63	3834
22-Jan-2010	10:15:00 AM	251	200000	0.141	5651.15	3467
22-Jan-2010	10:20:00 AM	344	200000	0.141	4123.37	2530
22-Jan-2010	10:25:00 AM	343	200000	0.141	4135.39	2538
22-Jan-2010	10:30:00 AM	357	200000	0.141	3973.22	2438
22-Jan-2010	10:35:00 AM	322	200000	0.141	4405.09	2703

APPENDIX VII

PV System Calculator Coding (Microsoft Visual Basic 2008)

Load Estimation Interface

```
Public Class Load_Estimation
    Dim F2 As New Efficiency_Estimation()
    Public Shared TOTAL As Label

    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button4.Click

        Me.Hide()
        Main_Page.Show()

    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button2.Click

        Me.Hide()

    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button1.Click

        Dim F2 As New Efficiency_Estimation()
        F2.Show()
        F2.lbl1.Text = Me.answer_load.Text
        Me.Hide()

    End Sub

    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button3.Click

        If Me.txt1.Text = "" Then
            Me.txt1.Text = 0.0
        End If

        If Me.txt2.Text = "" Then
            Me.txt2.Text = 0.0
        End If

        If Me.txt4.Text = "" Then
            Me.txt4.Text = 0.0
        End If

        If Me.txt5.Text = "" Then
            Me.txt5.Text = 0.0
        End If
```

```
        If Me.txt7.Text = "" Then
            Me.txt7.Text = 0.0
        End If

        If Me.txt8.Text = "" Then
            Me.txt8.Text = 0.0
        End If

        If Me.txtgen.Text = "" Then
            Me.txtgen.Text = 0.0
        End If

        Dim A As Double = Me.txt1.Text
        Dim B As Double = Me.txt2.Text
        Dim C As Double = 0.0
        Dim D As Double = Me.txt4.Text
        Dim J As Double = Me.txt5.Text
        Dim F As Double = 0.0
        Dim G As Double = Me.txt7.Text
        Dim H As Double = Me.txt8.Text
        Dim I As Double = 0.0
        Dim K As Double = Me.txtgen.Text
        Dim TOTAL As Double

        C = A * B
        F = D * J
        I = G * H

        TOTAL = (C + F + I) - ((C + F + I) * K / 100)

        Me.txt3.Text = C
        Me.txt6.Text = F
        Me.txt9.Text = I

        Me.answer_load.Text = TOTAL

    End Sub

    Private Sub CheckBox1_CheckedChanged(ByVal sender As
System.Object, ByVal e As System.EventArgs) Handles
CheckBox1.CheckedChanged

        If CheckBox1.Checked Then
            Me.txt1.Enabled = True
            Me.txt2.Enabled = True
        End If

    End Sub

    Private Sub CheckBox2_CheckedChanged(ByVal sender As
System.Object, ByVal e As System.EventArgs) Handles
CheckBox2.CheckedChanged

        If CheckBox1.Checked Then
            Me.txt4.Enabled = True
            Me.txt5.Enabled = True
```

```
        End If

    End Sub

    Private Sub CheckBox3_CheckedChanged(ByVal sender As
System.Object, ByVal e As System.EventArgs) Handles
CheckBox3.CheckedChanged

        If CheckBox1.Checked Then
            Me.txt7.Enabled = True
            Me.txt8.Enabled = True
        End If

    End Sub

    Private Sub Label6_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Label6.Click

    End Sub

    Private Sub Load_Estimation_Load(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles MyBase.Load

    End Sub

    Private Sub CheckBox4_CheckedChanged(ByVal sender As
System.Object, ByVal e As System.EventArgs) Handles
CheckBox4.CheckedChanged
        If CheckBox1.Checked Then
            Me.txtgen.Enabled = True
        End If
    End Sub
End Class
```

Efficiency Estimation Interface

```
Public Class Efficiency_Estimation
    Dim F3 As New Battery_Bank_Sizing()
    Public Shared newload As Label
    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles calculate.Click

        Dim A As Double = lbl1.Text
        Dim B As Double = Me.txt1.Text
        Dim C As Double = Me.txt2.Text
        Dim D As Double = Me.txt3.Text
        Dim F As Double = 0.0
        Dim G As Double = 0.0
        Dim H As Double = 0.0
        Dim newload As Double

        F = A / B
        G = A / C
        H = A / D

        newload = A / (B * C * D)

        Me.txt4.Text = F
        Me.txt5.Text = G
        Me.txt6.Text = H

        Me.lbl5.Text = newload

    End Sub

    Private Sub Button4_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button4.Click

        Me.Hide()
        Load_Estimation.Show()

    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button2.Click

        Me.Close()

    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button1.Click

        Dim F3 As New Battery_Bank_Sizing()
        F3.Show()
        F3.lbl1.Text = Me.lbl5.Text
        Me.Hide()

    End Sub
```

```
    Private Sub Label4_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Label4.Click

    End Sub
End Class
```

Battery Bank Sizing Interface

```
Public Class Battery_Bank_Sizing
    Dim F4 As New PV_Array_Sizing()
    Public Shared newload As Label
    Private Sub Button5_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button5.Click

        Me.Hide()
        Efficiency_Estimation.Show()

    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button2.Click

        Me.Close()

    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button1.Click

        Dim F4 As New PV_Array_Sizing()
        F4.Show()
        F4.lbl1.Text = Me.lbl1.Text
        F4.txt1.Text = Me.txt4.Text
        F4.lbl25.Text = Me.lbl7.Text
        Me.Hide()

    End Sub

    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button3.Click

        Dim A As Double = lbl1.Text
        Dim B As Double = Me.txt1.Text
        Dim C As Double = Me.txt2.Text
        Dim D As Double = Me.txt3.Text
        Dim F As Double = Me.txt4.Text
        Dim G As Double = Me.txt5.Text
        Dim H As Double = 0.0
        Dim I As Double = 0.0
        Dim J As Double = 0.0
        Dim K As Double = 0.0
        Dim L As Double = 0.0
        Dim total_battery As Double

        H = (A * 1000) / B   'load/battery voltage
        I = H * C   'total amp hr x day of autonomy
        J = I / D   'storage capacity/DOD
        K = J / G   'required battery capacity/single battery
capacity
        L = B / F   'system voltage/single battery voltage

        total_battery = L * K
```

```
        Me.lbl2.Text = H
        Me.lbl3.Text = I
        Me.lbl4.Text = J
        Me.lbl5.Text = K
        Me.lbl6.Text = L

        Me.lbl7.Text = total_battery

    End Sub
End Class
```

PV Array Sizing Interface

```
Public Class PV_Array_Sizing

    Private Sub Button5_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button5.Click
        Me.Hide()
        Battery_Bank_Sizing.Show()

    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button2.Click
        Me.Close()

    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button1.Click

        Dim F2 As New Efficiency_Estimation()
        Dim F3 As New Battery_Bank_Sizing()
        Dim F5 As New Results

        F5.Show()
        F5.lbl1.Text = Me.txt6.Text
        F5.lbl2.Text = Me.lbl6.Text
        F5.lbl3.Text = Me.lbl25.Text
        F5.lbl5.Text = Me.lbl5.Text

        Me.Hide()


    End Sub

    Private Sub Button3_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button3.Click

        Dim A As Double = lbl1.Text      'load from previous form
        Dim B As Double = Me.txt1.Text   'battery voltage
        Dim C As Double = Me.txt2.Text   'sunshine hours
        Dim D As Double = Me.txt3.Text   'pv module current
        Dim J As Double = Me.txt4.Text   'pv module voltage
        Dim K As Double = Me.txt5.Text   'pv efficiency
        Dim L As Double = Me.txt6.Text   'avg solar radiation
        Dim F As Double = 0.0            'avg daily A-h
        Dim G As Double = 0.0            'array current
        Dim H As Double = 0.0            'no of module in parallel
        Dim I As Double = 0.0            'no of module in series
        Dim M As Double = 0.0            'area of pv array
        Dim TOTAL_PVmodule As Double

        F = (A * 1000) / B               'avg daily A-h
        G = F / C / (J / B)
        H = G / D
        I = B / J
```

```
        M = A / (K * L)

        TOTAL_PVmodule = H * I

        Me.lbl2.Text = F
        Me.lbl3.Text = G
        Me.lbl5.Text = H
        Me.lbl9.Text = I
        Me.lbl10.Text = M

        Me.lbl6.Text = TOTAL_PVmodule

    End Sub

    Private Sub PV_Array_Sizing_Load(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles MyBase.Load

    End Sub
End Class
```

Result Interface

```
Public Class Results

    Private Sub calculate_Click(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles calculate.Click
        Me.Close()
        Main_Page.Show()

    End Sub

    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e
As System.EventArgs) Handles Button2.Click
        Me.Close()

    End Sub
End Class
```